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*State Research Station Blangstedgaard (E. Poulsen)*

# Fruit Trees and Climate. II.
# Mist Application, Soil Humidity and Fruit Development in Apple Trees

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**Resumé**

Træer af 'Golden Delicious' blev overbruset med en tåge af regnvand hver 10.-30. minut, når luftens relative fugtighed var under 85, 70 og 55 % for vækstsæsonerne i henholdsvis 1971, 1972 og 1973. Træer med og uden frugt og træer ved forskellig jordfugtighed indgik også i forsøgene.

Overbrusning havde ingen større positive effekter på vækst og frugtudvikling, heller ikke ved lav jordfugtighed. Tværtimod medførte overbrusning i de 2 år et forøget bladfald. Blade og frugten fik et kedeligt gråt skær, og forekomsten af skrub, lenticelplet og soddug blev i nogle tilfælde forøget. Frugtens syreindhold blev øget.

Lav jordfugtighed gav en ringere samlet tilvækst og mindre, men mere gule frugter, end hvor karrene blev vandmættet dagligt.

**Summary**

A mist of rain water was applied to trees of 'Golden Delicius' every 10th-30th minute in the growing seasons of 1971, 1972, and 1973, whenever the relative air humidity fell below 85, 70, and 55 %, respectively. The experiments were carried out on trees with different fruit loads as well as under different conditions of soil humidity.

No positive effects resulted from mist application. On the contrary, in two of the years leaf drop was increased. Leaves and fruits assumed a greyish tinge, and the occurrence of russeting, lenticel spot and sooty mould was in some cases increased. Also the acid content of the fruit was increased by mist application.

Low soil humidity compared to a daily water saturation of the pots reduced growth. The fruit were smaller, but more yellow.

## Introduction

At a low water potential the stomata of the leaves close and the intensity of photosynthesis and the growth are reduced. The growth of fruits depends upon the daily duration of stomatal opening (Furr and Magness, 1930). The water potential in plants is determined by the conditions for water uptake where soil humidity plays a rôle, and the potential evaporation where the relative air humidity is an important factor. The water potential of the leaves drops during the day and may stay low in dry periods, while fluctuations in the water potential of fruits are less (Chapmann, 1971 a, b; Goode and Higgs, 1973). Even on irrigated trees stomate are not open all day (Magness and Furr, 1930). Tromp and Oele (1972) found an increased shoot growth and fruit size at a minimum of 75 % relative air humidity compared to 45-55 %. In permanent irrigation

systems, in addition to actual irrigation, humidification of the foliage in hot, dry periods is feasible and it is possible that this would have an advantageous effect upon growth and fruit development. This matter has been elucidated in present experiments. Wetting the leaves with small amounts of water in the form of a mist at pre-set intervals of time has been used, since detrimental effects due to leaching of leaves, cooling etc. would appear to be smallest by this method.

Two experiments were carried out on trees at different soil humidities. Special attention was paid to the effects on trees with a good fruit load, since stomata are more open here than on trees with a low growth vigour (Hansen, 1971; Tunsuwan and Bünemann, 1973). Conditions inducing stomatal closure therefore may be harmful to fruit growth in particular.

**Material og methods**

Three-years-old trees of 'Golden Delicious' planted in a porous soil in 15 litres plastic pots with drain at the bottom were used.

*1971:* Trees were placed in 4 growth chambers from 16th June till October. In two of the rooms a mist of rain water was applied for 10 seconds every 10th-30th minute when the relative humidity of the air fell below 90 %. The intervals between mist application were shortest in hot periods. Control unit: Honeywell. Two other rooms were without mist application. The experiment is described elsewhere (Hansen, 1975), only some effects upon fruit and leaf development are mentioned here.

*1972:* The experiment was carried out in open air from 9th June till 20th October. Mist was applied for 5 seconds every 20th minute (in a few hot periods every 10th minute), when the relative humidity of the air was below 70 %. The leaves were covered with water without appreciable dripping from the trees. Comparable trees without mist application were placed at a distance of ca. 50 meters.

Also different fruit load and different soil humidity were incorporated into the experiment. But due to a special technique of watering the trees the growth level was low. Therefore only a few undisguised effects will be mentioned.

*1973:* The experiment started on the 5th of July in the open air.

1. Mist application, 'high' soil humidity
2. » » 'low' » »
3. Without » 'high' » »
4. » » 'low' » »
5. » » intermediate soil humidity

Mist was applied for 5 seconds every 10th minute, but only when the air humidity was below 55 %. At 'high' soil humidity 1-3 litres of nutrient solutions were supplied to each tree per day; in hot periods the larger amounts were given in two batches a day. At 'low' soil humidity, for two periods of each 2 days per week nutrient solution was omitted. In the interim the pots were saturated with nutrient solution. In September the periods without water supply were extended to 3 days, and from 24th of September till 28th of October to 6 days. At intermediate soil humidity the pots received no water every second day. Rain was excluded from the pots by a plastic cover.

The nutrient solution contained the following elements in milliequivalents per liter: N 9, P 4, K 2, Mg 4, Ca 5. Also micronutrients were included. Each treatment was given to 9 trees. The fruits were harvested at the end of October and kept in storage at 1° C until the middle of April. After leaf fall the trees were separated, dried (80° C) and weighed. The relative air humidity was registered by a hygrograph.

**Results**

**Air humidity and frequency of mist application**

*1971:* The relative air humidity was quite high in the rooms even without mist application.

Only in sunshine did it drop to 40-60 % as against 70-80 % with mist application.

*1972:* In periods of 4-10 hours daily the relative air humidity under natural conditions dropped to 50-60 % for 27 days, to 40-50 % for 24 days, and to 30-40 % for 10 days. Mist was applied intermittently on an average for 9.1 hours daily June 16 - July 15, for 8.4 hours daily July 16 - August 15, and for 7.9 hours daily August 16 - September 15. The total number of mist applications was above 2300.

*1973:* Mist was applied intermittently on an average for 3.4 hours daily July 5 - July 31, for 7.6 hours daily August 1 - August 31, and for 3.4 hours daily September 1 - September 20. The total number of applications was about 2350 but compared to 1972 the frequency was doubled, although the number of hours with mist application was only half.

**Occurrence of symptoms**

*1971:* Leaves dropped to some degree during the season in the rooms with mist application.
*1972:* Leaf drop on some trees about August 10 was a little delayed by mist application. About September 20 yellowing and drop of leaves started at trees with mist application. Leaves, partly fruits, were greyish.
*1973:* Contrary to the other years no leaves dropped during the growing season. However, with mist application yellowing and leaf drop started in the beginning of October, and also this year leaves and fruits were grey. A 1 minute treatment of leaves in 0.3 N $HNO_3$ followed by distilled water did not reduce the value of nutrients by analysis.

**Growth, yield and fruit development**

In 1972 the growth level was low and fruit set varied. Therefore no clear conclusion on

*Table 1. Effect of mist application and different soil humidity on growth and fruit development. 1973. Average of 9 trees. LSD = least significant difference (95 % level)*

| Mist application | + | + | — | — | — | |
|---|---|---|---|---|---|---|
| Soil humidity | high | low | high | low | interm. | LSD |
| *October 1973:* | | | | | | |
| kg top+roots/tree[1]), dry weight .... | 1.22 | 1.16 | 1.08 | 1.09 | 1.07 | 0.13[4]) |
| kg top+roots+fruits, dry weight.. | 2.66 | 2.33 | 2.69 | 2.29 | 2.49 | 0.30 |
| Number of fruits/tree ..... | 86 | 82 | 99 | 98 | 98 | 16 [4]) |
| kg fruits/tree, fresh weight ..... | 9.6 | 7.8 | 10.7 | 8.0 | 9.4 | 1.3 |
| g/fruit, fresh weight ..... | 113 | 97 | 111 | 83 | 100 | 13 |
| Colour of fruits[2]) ..... | 2.0 | 2.9 | 2.5 | 2.7 | 2.9 | 0.5 |
| *April 24, 1974:* | | | | | | |
| Colour of fruits[3]) ..... | 4.2 | 4.7 | 4.0 | 4.6 | 4.3 | |
| % stark yellow, size 55-60 mm .... | 38 | 74 | 44 | 74 | 55 | |
| % stark yellow, size 60-70 mm .... | 64 | 91 | 44 | 82 | 72 | |
| % with heavy russeting ..... | 3 | 3 | 1 | 1 | 1 | |
| % with minor russeting ..... | 33 | 28 | 6 | 15 | 10 | |
| % with lenticel spot ..... | 42 | 63 | 10 | 21 | 21 | |
| Acid content ..... | 6.1 | 5.3 | 3.9 | 3.4 | 3.0 | |
| Refractometer value ..... | 12.5 | 13.3 | 11.6 | 12.7 | 12.7 | |

[1]) excl. leaves.
[2]) 5 = yellow, 0 = green.
[3]) See Table 2.
[4]) Significant effect of mist application.

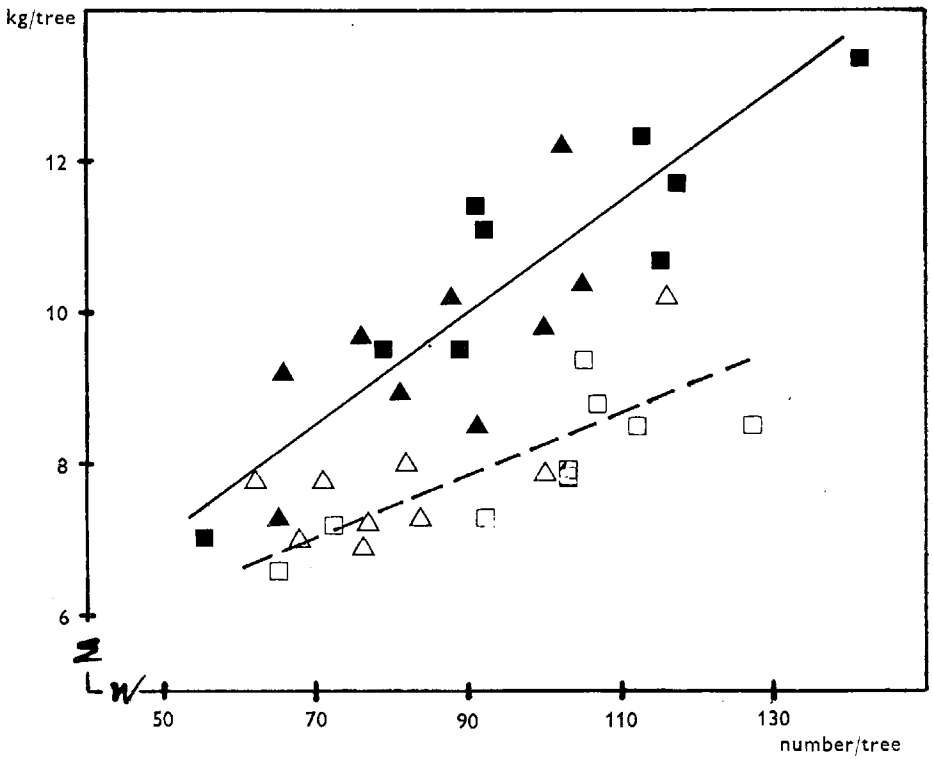


Figure 1. *Relationship between number and kg of fruits per tree.* 1975

■ High soil humidity, without mist application
□ Low – – , – – –
▲ High – – , with – –
△ Low – – , – – –

the basis of well cultured trees can be reached. However, there was no clear indication of either a positive or a negative effect of mist application.

Also in 1973 the growth level in vegetative parts was low, but this can be attributed to the rather heavy crop. As treatments started on July 5, effects on shoot growth would be only small. However, the total vegetative growth was a little greater with than without misting, but this difference disappears when the fruits are included (Table 1).

Fruit number per tree in 1973 was greater without than with mist application (Table 1).

*Table 2. Effect of mist application on fruit development. Oct. 1971. 'Open air' is trees under natural growth conditions*

| | With mist | Without mist | 'Open air' |
|---|---|---|---|
| Number of fruits/tree ... | 26.3 | 17.9 | 25,5 |
| kg fruits/tree ..... | 3.05 | 2.58 | 3.23 |
| % with heavy russeting.. | 30 | 4 | 6 |
| % with minor russeting.. | 30 | 25 | 10 |
| % without russeting .... | 40 | 70 | 77 |
| Colour[1]) ..... | 45 | 51 | 79 |

[1]) Colour = (100 × kg strongly coloured + 67 × kg medium coloured + 33 × kg faintly coloured + O × kg green)/kg total.

Yield and average fruit size at a given number per tree were distinctly lower at 'low' than at 'high' soil humidity, whereas an effect of mist application was not clear (Figure 1).

In 1971 the colour of the fruits was not clearly affected (Table 2). Immediately following harvest in 1973 fruits were more green at a contemporary mist application and 'high' soil humidity (Table 1). After storage the fruits within a certain size group turned more yellow the lower the soil humidity had been.

The occurrence of russeting and lenticel spot was increased by mist application (Tables 1 and 2). Sooty mould was very distinct on misted fruits from 1972 after storage till early summer next year. Analysis of fruits from the 1973-experiment showed, within the same grade, a higher acid- (and perhaps sugar-) content after mist application (Table 1). There was a tendency to a lower acid-content, but a higher sugar-content (refractometer value) at 'low' than at 'high' soil humidity.

**Discussion**

Mist application in a growth chamber in 1971 increased shoot growth a little, but only in trees without fruits (Hansen, 1975). Even at low soil humidity mist application had no obvious positive effects, not even in 1973, when mist was applied only at a relatively low air humidity. Fruit growth was not increased either, despite the fact that the stomata of the leaves on well-watered fruit-bearing trees show a fairly high degree of opening (Hansen, 1971; Tunsuwan and Bünemann, 1973), so that stomata probably would have closed at low soil humidity. On the contrary, negative effects of mist application turned up in several cases. One of the reasons may be a cooling effect of the mist on leaves and fruits. Overtree sprinkler irrigation of apple trees several hours a day at temperatures above 30 °C reduces fruit temperature in particular (by 5-6° or more), but also air- and leaf temperature (by 1-3°, Unrath, 1972 a). Shoot growth is reduced by decreasing temperature (Hansen, 1975). Deposits on leaves and fruits due to mist application may also have had unfavourable effects. Lower leaf surfaces have been wetted in some cases as well. This may have inhibited penetration of carbon dioxide through stomata.

An increase of water potential in leaves have been shown in English field experiments by mist application. Trunk growth was increased, but no other clear effects on growth or yield were shown (Goode, 1971, 1972, 1973). A supply of 35-80 mm of 'rain' per season, in portions of 0.5-1 mm in hot and dry weather, increased yield in some cases, but examples of the opposite effect also turned up (Hilkenbäumer, 1971). Overtree irrigation for longer periods at temperatures above 30° C promoted harvest time; fruit colour was increased, in one year also fruit size, and in another, bitterpit was reduced (Unrath, 1972 b, 1973; Unrath and Sneed, 1974). However, the normal Danish weather is considerably cooler than that. Positive effects of a mist application might occur only in hot periods with a high potential evaporation, which are normally scarce under Danish conditions, or if the air is humidified by another technique wihtout a direct wetting of the leaves (Tromp and Oele, 1972).

It is clear, however, that a good water supply through the roots is important for the function of the leaves and for the growth, fruit yield and fruit size (cf. Furr and Magness, 1930; Heinicke and Childers, 1935; Goode and Hyrytz, 1964; Cripps, 1971; Fiedler and Weier, 1971 a, b; Goode and Ingram, 1971; Assaf et al., 1974). This was especially obvious in 1973. However, fruit colour increased at the lower soil humidity, together with a tendency to a lower acid- and a higher sugar content of fruits (cf. Guefat'Reich et al., 1974). The treatments affected the nutrition of the trees as well. The percentage of potassium in the leaves was lower in trees at low than at high soil humidity (Hansen and Poulsen, 1974). This *may* have contributed to the reduced growth and yield here as well.

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